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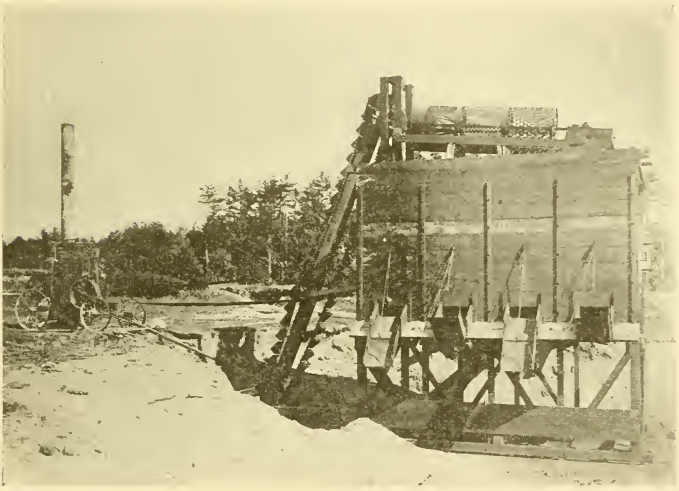
NEW HAMPSHIRE COLLEGE
AGRICULTURAL EXPERIMENT STATION

EXPERIMENTS IN ROAD SURFACING



Machine for Lifting and Screening Gravel

BY CHARLES H. PETTEE

NEW HAMPSHIRE COLLEGE
OF
AGRICULTURE AND THE MECHANIC ARTS
DURHAM

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EXPERIMENTS IN ROAD SURFACING

BY CHARLES H. PETTEE

OBJECT OF EXPERIMENTS

In July, 1895, and in June and August of 1896 road experiments were carried on which were described in detail in Bulletins 30 and 46, issued by the New Hampshire College Agricultural Experiment Station. On page 76 of the latter Bulletin it was indicated that certain experiments in road surfacing had been postponed to a more convenient season. This work was taken up in March, 1898, and completed in June of the same year, the work being spread over a considerable time for financial reasons. The results of this latter work have been carefully followed for two years, and the results of that described in Bulletin 30 for five years. In addition, some work in the same line by town officials has been noted and comparisons made which are hereinafter contained.

In the fall of 1898, through the courtesy of W. A. Cook, Jr., representing the Climax Road Machine Company of Marathon, N. Y., machinery for hoisting, screening, and storing gravel, was placed at the disposal of the writer for the purpose of still further elucidating the problem of road surfacing. The apparatus was set up at the gravel bank near the college reservoir, as per frontispiece, and experiments have been carried on from time to time, which will be explained in detail in proper place. The object of all these experiments was to throw additional light, if possible, upon the subject of surfacing country roads and especially to emphasize such practical results as are of general utility.

SURFACING CARRIED ON DURING SPRING OF 1898

Plate 1 gives elevation and plan of a portion of the highway surfaced during this experiment. It was the same section

that had been graded two years before, and it has been described in detail on pages 60–63 of Bulletin 46. It may be recalled that the earth fill forming the upper foot of grade of this road was largely clay and a clayey hardpan, thoroughly drained for most of the distance by a rock fill underneath. The road was divided longitudinally into sections of fifty feet each except that several sections were shortened (see plan) because sufficient surfacing material of certain kinds was not available for full lengths. The following table shows in detail what was done upon each section :

Section.	Length in feet.	Width in feet.	Depth of material in inches before rolling.	Number loads, 42 cubic feet each.	Materials used.
1	30	9	5.6	3.	G. Chesley gravel, screened.
2	45	9	6.2	5.	G. Chesley gravel.
3	50	9	4.5	4.	Lee gravel.
4	50	9	5.6	5.	Reservoir screened gravel.
5	50	9	5.6	5.	Reservoir gravel.
6a	15	9	7.0	0.5 1.5	Clay. Coarse reservoir sand.
6b	35	9	5.6	3.5	Coarse reservoir sand.
7	50	9	5.6	5.	Lee gravel, screened.
8a	10	14	9.0	2.5	Coarse sand, rolled.
8b	40	14	9.0	10.	Section macadamized with Lee gravel, screened, sorted, and rolled.
9	50	14	5.8	8.	Lee gravel, screened and sorted.
10	13	14	5.5	2.	Point rock mixed with earth.
11	24	14	6.0	4.	Point gravel.
12	13	14	5.5	2.	Point beach rock.
13	50	14	5.8	8.	E. Emerson gravel.
14	50	0 9	0. 1.7	0. 2.	Nothing for one year. E. Emerson gravel, 2d year.
15	50	14	7.2	4. 6.	Stones 2 to 6 inches through. Screened reservoir gravel.

DESCRIPTION OF MATERIAL USED

The G. Chesley gravel is a loose, silicious, water-worn material, with no clay admixture, containing very few stones

Plate 1

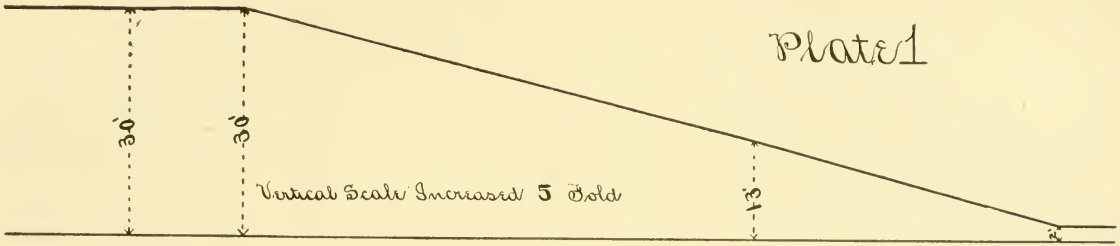

Fig. 1, (Elevation).

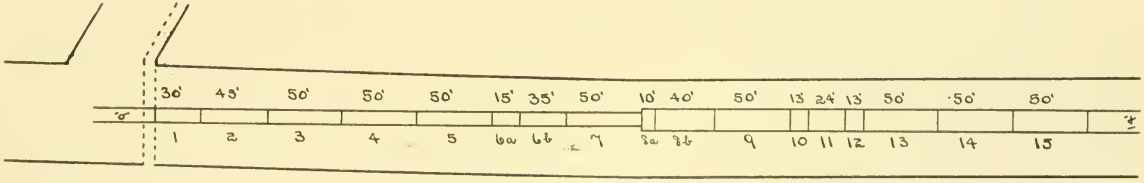

Fig. 2, (Plan).

larger than one and one half inches largest dimension, and from ten to fifteen per cent. of sand. This sand was screened out for section one.

The Lee gravel is a material similar to the above except that a considerable portion of the bank where it is obtained contains a much coarser article and this kind was used exclusively. Perhaps three fourths of this gravel consists of smooth water-worn stones, from one to four inches in largest dimension. It contains much less fine sand than the Chesley gravel and was used upon sections 3, 7, 8b, and 9. It was screened and sorted for section 8b into three qualities; for the bottom layer one and one half inches and larger; for the middle one, one half inch to one and one half inches, and finer for the binder layer. A little clay was added to the binder layer to make it more adhesive.

The gravel for section 9 was screened only once, separating the above material into coarse and fine, about on the one inch line.

The screened gravel of section 7 was freed from fine sand by a screen of about one-fourth inch mesh.

The reservoir gravel which was employed upon sections 4, 5, and 15, is finer than the Chesley in structure. It contains very few stones larger than one inch largest dimension, and has as small a proportion of sand as the Lee gravel. It has a small admixture of clay which gives it, with one exception, the best binding quality of any material used. As employed on sections 4 and 15, the small quantity of sand it possessed was screened out.

The coarse reservoir sand used on sections 6a and 6b was taken from a different portion of the same bank from that above, was of much finer texture, and contained no clay. Probably three fourths of the whole was a sharp plastering sand, the remainder consisting of small pebbles of the nature of that used on sections 4, 5, and 15 as above.

The coarse sand of section 8a and the Point gravel of section 11 were of substantially the same composition as the foregoing.

The E. Emerson gravel, as employed upon sections 13 and 14, is similar to that already described, resembling most the

G. Chesley gravel but containing a considerably larger proportion of sand.

In the easterly part of Durham are found extensive deposits of an argillitic, quartzite rock, having much of the appearance and many of the qualities of the traps. These deposits occur all the way from Dover on the north to Stratham and Newfields on the south. They form the whole, or at least a large part, of the bed of Great Bay, and at various points along this waterway, water-worn pebbles of this rock may be shoveled up in considerable quantity at low tide. This was the rock used upon section 12. It is the same that is employed by the city of Dover for macadamizing its streets, except that there it is taken from a quarry. It is hard—easily scratching glass—tough and compact. Like the traps it breaks up easily along seams and joints into manageable sizes when attacked in the quarry with dynamite, and is thus fitted with comparative ease for the crusher. It breaks a little too much on the slatey line to compare with the best traps, but like them possesses good wearing and binding qualities.

In many parts of Durham near Great Bay are found banks of earth mixed with fragments of this same rock. It is not then water worn, neither do we find it in small pebbles as on the beach. It is simply earth and fragments of stone varying usually from one to six inches largest dimension. This mixture was tried upon section 10.

It was at first intended to make the whole of section 8 alike, but when the available quantity of material was found deficient, ten feet at one end of the section was set apart as 8a and filled in with the screenings left over from the other sections. This coarse sand was thoroughly wet and rolled and every effort put forth to consolidate it into a hard and durable road surface. In truth, it made an excellent road for some time, and could hardly be distinguished from the macadamized section adjoining for several months. Upon the balance of section 8, marked 8b, an attempt was made to have a complete macadamized road constructed out of gravel. The gravel was screened, sorted, put on in layers, the coarser at the bottom, and each layer rolled as is usual in such construction. The two obvious obstacles to success in employing this

material were its water-worn, rounded surfaces and its lack of homogeneousness because of the presence of a considerable per cent. of softer rock made more or less rotten by being imbedded in the gravel bank for ages. The top layer was composed of sand with a small admixture of clay to make a better binder. The immediate success in securing a good hard surface was surprising as well as gratifying.

Section 15 before surfacing was the muddiest at certain seasons of all, and its treatment was arranged accordingly. About four inches' depth of angular stone, picked up by the roadside, was spread uniformly and then covered with six inches of reservoir gravel. The section has never been muddy since its treatment.

All of the above described materials were in use in the town for road surfacing, and they were got together in adjacent plots in order to obtain comparative results. After the work was completed the surface of all the sections was uniform from top to bottom of hill, except that section 8, with its 9 inches in depth of surfacing material, projected above the general level, and section 14, with nothing, was depressed below.

Next to No. 15, sections 7, 8, and 9 possessed the most treacherous subsoil, viz.: a clay not underlaid with stone. The lower half of the road treated possessed a flatter cross section than the other, which was one reason why the surfaced portion was widened here.

RESULTS AFTER TWO YEARS

The most striking feature to a person riding over the road at this writing is the existence of depressions over sections 6a, 6b, 8a, 11, and 14, of 4 inches, 4 inches, 3 inches, 4 inches, and 6 inches respectively. The depression over No. 14 of 6 inches was to be expected. The increase of the depression from 4 inches to 6 inches illustrates the tendency of depressions once started to increase under traffic. The remaining four are the only instances among the whole seventeen plots where fine gravel or coarse sand was used for surfacing, and show conclusively that sand, even if mixed with a clayey earth, does not stand up with rock. In short, it lacks

cohesion, and consequently durability Evidently, for a similar reason, section 1 has stood up somewhat better than section 2, which contains more sand; also section 7 than section 3.

Again, wherever, as in sections 1, 2, 3, 4, 5, 7, and 9, water-worn gravel was used, which contained more or less large stones, the coarse material not being screened out in any of these cases, many of these have bedded near the surface, and the finer material has worn away, leaving the stones projecting to some extent. This makes the surface uneven and jolty to ride over. The general appearance is that of a macadamized road which has worn down so that it needs resurfacing. If, however, the larger stones had been kept out, or if they had been put in as a separate lower layer and rolled in place, the surface would have kept smooth some years longer. Section 9, where the gravel was sorted, and the coarser material placed at the bottom, is noticeably better than the others in this respect, but as it was not rolled there was more or less mixing of the different layers during consolidation. Section 8b remains smooth to-day, and, with the exception of No. 12, is in by far the best condition of all.

Sections 4 and 5, which were remarkably smooth the first year, are now worn flat, and need resurfacing. The material used upon these sections was finer than that upon most of the others, as already noted, hence its less durability. For the same reason the few large stones contained project prominently, and render the present surface unusually rough.

Section 6a was noticeably harder and smoother than section 6b, for the first year, though slightly more muddy in the spring. There was no great depth of mud in either case, however.

Section 10 has made a fair road, but not as hard or durable as several others. It may be placed, in order of durability, between the coarse and fine graveled sections already described.

Section 12 is the best of all, and stands up to-day almost as well as when first laid. The section was too short for best effect, and the material has been pushed either way to some extent upon the poorer sections adjacent. Section 8b is the

only one to compare with it, but the material of section 12 contains absolutely no rotten stone, and the plot compares favorably, thus far, with the macadamized road described in Bulletin 30, which is surfaced with Salem trap rock.

Plot number 13 seems to have worn most nearly like numbers 4 and 5. The cross section is now flat, and the surface needs a new coat of gravel.

Section 14 has received just enough gravel to keep it from being much muddy in the spring, but it has worn flat and hollowing.

In section 15 a few of the large bottom layer stones have worked to the surface, and produce the same unevenness that has been noted in some other plots.

The macadamized section of 125 feet in length described in Bulletin 30, has been tested now for five years, and, with the exception of some 12 feet at the easterly end, has stood up perfectly. This particular portion was purposely underlaid with several inches of clay, with a clay subsoil underneath that, and, during the first spring following its construction, heaved and settled unevenly. It does not seem to have been affected much since, but it shows conclusively that extra care and depth of surfacing material are necessary with a clay subsoil. There is a marked difference, evident at first inspection, between the wearing qualities of a first-class macadamized surface, say of Salem crushed stone, and of one made from silicious, water-worn stones found in gravel banks. The case of section 12, however, shows that the difference is more in the quality of the rock used than in the shape of the pieces, the water-rounded pieces having bonded together surprisingly well, though, of course, the angular fragments would be preferred.

WORK BY TOWN OFFICIALS

A commendable practice prevails in some towns of graveling immediately after using the road machine in the early spring, the gravel thus covering up and helping to smooth over the inequalities due to the running of the machine. In such cases a very successful practice consists in dumping a load of gravel about once in eighteen to twenty feet, and spreading this not over five feet in width along the centre of

the traveled way. The gravel mixes with the material stirred up by the machine, and together they consolidate into a fairly smooth road surface. A second graveling the next year, when the ground is soft in the spring, or later, if rains are abundant, will produce a very excellent road, and thereafter, if the first use of the machine has been thorough, there will be no further need of its employment, as a little gravel, applied every few years as needed, will keep a first-class surface. In following numerous such examples, I have noted a very general practice of employing too fine a material. If the ground is soft and the soil heavy, the sand will mix with the natural earth and improve the surface, though not as much so as if a coarser gravel were used. It becomes, in such case, merely a question of comparative cost of the two materials. It should be remembered, however, that if sand is used it must be put on in small quantities at a time, and the greater necessity exists of having it consolidated early in the spring. With an average New England condition as to rain-fall, a coarser gravel may be easily consolidated without sensible waste at almost any season. With sand, however, especially on a grade, a considerable portion will be found in the side ditches unless almost immediately consolidated with the natural earth beneath, and this can only be accomplished when such earth is reasonably soft, as in the spring. If there is no washing away of the sandy material, and no heavier soil with which it may form a mixture, it will make a loose, sandy road, very disagreeable for travel, and requiring nearly the maximum of animal force to accomplish a given amount of work.

It is often advisable to haul upon a road a layer of clay or hardpan before the gravel is put on. Nothing short of a pavement, not even a macadamized surface, will withstand the washing of heavy rains upon a steep grade better than a properly compacted combination of clay and gravel.

SCREENING GRAVEL

Early in the above experiments it was seen that the question of a uniform size of product for each layer of surfacing material would be an important one, and when in the fall of 1898 an opportunity offered to experiment with screened

gravel it was quickly availed of. The frontispiece illustrates the hoisting, screening, and storing apparatus, already referred to on page 1, in running order, and indicates, without need of detailed explanation, the practical objects accomplished by its use.

Before the overwhelming nature of the proof of the advantages of a nearly uniform size of stone, rolled separately in layers, was apparent as a result of the experiments already instituted, it was thought that possibly there might be saving enough in handling the product by use of elevated bins to nearly pay for the extra expense of running the hoisting and screening machinery. When later came the proof of the great advantage in quality of the product thus furnished, the importance of the experiment was enhanced.

The location of the apparatus, as given on page 2, was not favorable for the best results. The gravel bank was little more than a sand bank, and the screener was not adapted to the work of thoroughly separating a product containing so large a per cent. of sand. However, this did not appreciably affect the question of the cost of handling the material, and experiments were carried on especially to test this point. It is recognized, however, at the start, that particular experiments of this sort are not necessarily conclusive. The writer has found that the cost of handling by cart with hand labor various kinds of earth with short hauls, say under one and one half miles, without any absolute neglect in supervision, has varied from thirteen to sixty cents per yard, and some of the longer hauls have been effected and harder materials have been handled for the smaller figures. There is, perhaps, no part of road work more difficult to carry on successfully from a financial point of view than this, because it is so generally done either piecemeal or without competent supervision.

It was, therefore, a pleasure to note, as a result of experiment, that if hoisting machinery were used at all, it would be likely to receive better than average supervision. 2d. The shoveling into the carrier was easy, and therefore fair results were attained with very little supervision. 3d. The loading of teams was so easy that there was no disposition—so common in hand work—to go off with half a load, or to dally on

the road to avoid so much shoveling. 4th. All disposition to load with the finer material because it shoveled easier was eliminated. 5th. The average time at the bin in loading was five minutes when no pressure was applied. If in a hurry, a team would go out in two minutes. On the contrary, a driver would take ordinarily at least thirty minutes to load up alone by hand, and would average twenty minutes when extra shovelers were furnished. 6th. Three men, one for running the machinery and two for shoveling, would keep six teams running on a haul of 1¼ miles from the bank, increasing the number of trips by at least two, the average size of load by one third, and the quality of the product by a large per cent., if the screen were adapted to the work in hand.

In short, without multiplying figures, the results showed that, speaking conservatively, graveling can be done on a considerably larger scale by the aid of hoisting and screening machinery, without extra expense, and the product will be very much improved. We advise our larger country towns to investigate the subject further, and see if there is not something in the suggestion adapted to their needs.

MACADAM, GRAVEL, AND EARTH ROADS

So much is being written and spoken about macadam, gravel, and earth roads, without adequate explanation of the distinctions between them and of their several advantages and disadvantages, that a few words on the subject are inserted here for general enlightenment. No distinction will be made in this connection between the Macadam and Telford systems.

A macadam road is one surfaced with crushed stone, put on in layers, the coarser usually at the bottom, and each layer rolled separately. The depth varies with the nature of the traffic and of the foundation, and with the special ideas of the engineer in charge. In all cases the object should be to obtain a sufficient body in the lower layers to hold up the traffic out of the softer material beneath at all seasons, and to furnish a surface layer which should be reasonably durable, be hard and smooth while it lasts, and capable of being replaced when worn without serious disturbance to the foundation.

A gravel road is one surfaced with material containing a large per cent. of rock, not usually sorted as to size, and a certain per cent. of earth which may be sand, clay, hardpan, or a mixture of two or more of these.

An earth road is one surfaced with a large per cent. of earth, which may be sand, clay, hardpan, loam, or a mixture of some of these. A very common idea of an earth road is one surfaced with the natural material where the road is built. This description, though generally characteristic, does not give the true distinction between these and gravel ones and may convey an entirely wrong impression. The true distinction lies in the predominance of earth over rock or the reverse in the surfacing material. Again, it will be seen that the gravel road is intermediate between the earth and the macadam and that there is no absolute line separating the earth from the gravel or the gravel from the macadam. The latter statement will appear evident if we consider that it makes no difference whether the stone for a macadam road has been prepared by a stone crusher or broken by the processes of nature and deposited in gravel banks during the glacial epoch.

Having defined the standard kinds of road surface we can now profitably discuss the advantages and disadvantages of each. We will assume that proper grades and suitable drainage have been provided and that all surfaces are in a fair condition of repair. The macadam road is hard and fairly smooth. It will be very smooth when new but is apt to wear rough under average treatment. It is dry during the spring months and will stand up under heavy, though not the heaviest, traffic. For the latter nothing but a pavement will suffice. On the other hand the macadam surface is disagreeably dusty and liable to ravel during dry weather; is hard on horses' feet and is expensive to construct and maintain.

The earth road, under favorable conditions of moisture and repair, is the smoothest, most elastic, and most pleasant for pleasure driving of any in existence. It is safest for horses' feet and, where the natural soil is favorable, is by far the cheapest both as regards construction and repair. On the other hand, if it is an ideal summer road, it is reasonably sure to be muddy and rough for perhaps two months in the spring as

well as during and following heavy rains at other seasons. In short its perfection for all seasons is apparently impossible and it depends upon constant, though inexpensive, attention to minute repairs for its favorable condition during a limited season.

It thus appears that, if we aim at durability, nothing less than a body of rock will keep us up out of the mud in the spring; that this will render the surface too dry for comfort and durability during the summer, and that the more expensive and more perfect the surface constructed upon this foundation, the more expensive and more difficult the matter of repair. In the city sprinkling has given greater durability and comfort to the macadam surface, and the heavy expense for construction and maintenance can often be easily borne. In the country these favorable conditions are usually absent. Some have attempted to find in the gravel road the safe middle course between the earth and the macadam. They do not, however, appear to have wholly succeeded.

Smoothness, elasticity, freedom from dust, low cost, and cheapness of maintenance seem to be thus far more or less incompatible with durability and constancy throughout the year.

It remains to be proved whether oiling the surface of a dirt road which has been underlaid where necessary by some form of rock to maintain the body of the road-bed or planting trees thickly on both sides of such a highway to conserve by their shade the natural moisture, will furnish to important country roads of not the heaviest traffic the combined qualities of smoothness, elasticity, freedom from dust, ease of repair, fair durability, and not excessive first cost. The despised clay may yet furnish the body of a material which will possess many of these desirable qualities when drainage can be thoroughly attained. With a substratum of crushed stone or coarse gravel or for a road surface close to ledge, no ordinary material can surpass it, especially on a grade. At any rate the necessary limitations of first cost should impel us to make a careful study of combinations of natural materials with a view to their most effective utilization. We can afford to clay, gravel, or sand a road when macadamizing would be out of the question.

We ought to have a clear idea of the effect of each such application before undertaking its use.

SUMMARY

The most important results of the above experiments and observations may be summed up in four sentences:

1. Country towns should do more surfacing, using the best materials available.

2. Sand should be removed from the gravel employed and all gravel should be as uniform as possible.

3. Labor-saving machinery should be utilized to reduce expense.

4. Combinations of natural materials should be tried when the conditions are favorable.